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RESEARCH ARTICLE **Open Access**

Physiological demands of road sprinting in professional and U23 cycling. A pilot study

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Abstract

This pilot study described and compared the power output (absolute, relative to body weight and relative to frontal area) recorded during successful road sprints in professional and under 23 men's cycling races. The study also described the exercise intensity and requirements of sprinters throughout final 10 min of the race. Nine successful (top 3) sprints performed by a professional (PRO: 23 y old, 1.76 m, 71.8 kg) and an under 23 (U23: 18 y old, 1.67 m, 63.2 kg) cyclist sprinter were analysed in this study. No statistical differences were found in absolute peak and average sprint power (PRO: 1370±51 W and 1120±33 W; U23: 1318±60 W and 1112±68 W). The average power output relative to body weight and to projected frontal area (A_p) was lower in PRO than U23 (15.6±0.4 and 17.4±1.1 $W{\cdot}kg^{-1}$; and 2533±76 and 2740±169 $W{\cdot}A_p^{-1}$, respectively) (P=0.016). The intensity of the last 10 min prior to the sprint was significantly higher in PRO than U23 (4.6±0.3 and 3.7±0.2 $W{\cdot}kg^{-1}$, respectively) (P<0.05). Races duration, total elevation gain and average power were similar between PRO and U23. In conclusion, the physiological demands leading into road sprinting (intensity of the last 10 min) were found to be higher in PRO compared to U23 races; however, a similar sprint power output (>2500 $W{\cdot}A_p^{-1}$ or >15.5 $W{\cdot}kg^{-1}$ for approximately 14 s, with a peak power output >3100 $W{\cdot}A_p^{-1}$ or >19 $W{\cdot}kg^{-1}$) indicates that sprint characteristics may be somewhat similar between PRO or U23 races. Further research is warranted in order to better understand physiological and tactical aspects important to road sprint cycling.

Keywords: anaerobic, sprint, cycling, performance, racing, male

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Introduction

Several studies have described and compared the anthropometric and physiological characteristics of cyclists from various disciplines, specialties and levels of competition (Lucia et al. 1998; Moseley et al. 2004). Generally, these studies have examined the cyclists' aerobic characteristics, with few studies reporting performance in efforts with durations relevant to sprinting (i.e. ≤ 30 s). Interestingly, similar absolute (W) and relative ($W{\cdot}kg^{-1}$) power outputs have been reported between high and low level male junior cyclists (Menaspà et al. 2012), and between under 23 and professional male cyclists (Sallet et al. 2006), during laboratory based sprint tests (i.e. 5 to 30 s duration). However, these tests were performed with participants that were not exclusively sprint specialists and under laboratory and not race conditions.

Despite the frequency of sprints in road cycling (e.g. ~7 out of 21 stages within Grand Tours) limited scientific research is available, with only one study reporting the power output of a single cyclist winning one race (Martin et al. 2007). Moreover, in road cycling the number of successful sprinters is somehow limited (e.g. 1 or 2 riders out of 30 per team). These factors, together with the complexity of road sprinting, may be the reason for the lack of scientific research describing the physiological demands of road sprinting. In fact, little is known on the characteristics and performance demands of road sprinting. Thus, research on road sprinting is novel, nevertheless logistically difficult to study with a sample. Still, considering that successful sprinters must produce a minimum amount of power to defeat their opponents, even just limited data can illustrate successful performances.

To date, a considerably greater body of literature has examined sprint performance during track cycling. While it has been suggested that maximal power may be a predictor of sprint performance, Dorel at al. (2005) found that average sprint speed during track cycling was not correlated with maximal power output (in W or $W{\cdot}kg^{-1}$) but instead significantly correlated with power output relative to the cyclists frontal area (r = 0.75, p = 0.01).

To the best of our knowledge, no study has examined the sprint power output of road cyclists competing at different levels of competition, or reported the sprint power output in relation to frontal area. Thus, in order to better understand the physiological demands of road sprinting, the main aim of this study was to describe and compare the power data (absolute, relative to body weight and projected frontal area) recorded during successful road sprints in professional and U23 male cycling races. Moreover, a secondary aim of this study was to examine the intensity in the final 10 min of the race to describe the difficulties that a sprinter has to overcome to be in contention for the sprint.

It was hypothesised that the sprint power output relative to frontal area will be similar between successful professional and U23 sprints; however the intensity in the final kilometres of the race will be higher in professional road competitions.

Materials and methods

Subjects

The subjects of this investigation were a male professional cyclist, competing for a UCI World Tour team in his fourth year as a professional cyclist (PRO: 23 y old, 1.76 m, 71.8 kg) and a male non-professional cyclist competing at International level for his first year in the UCI Under 23 category (U23: 18 y old, 1.67 m, 63.2 kg). The participants were successful road cycling sprinters and the performances analyzed in this study included at least 3 winning sprints for each rider, in their respective categories. The participants provided written informed consent to participate in this study, which was approved by a University Human Research Ethics Committee. The study meets the international ethical standards described by Harriss and Atkinson (2011).

Design

The study was a retrospective observational double case study. The study was conducted in the field in order to maximize the ecological validity of the results.

Methodology

Performance data of the cyclists over an entire road cycling season have been collected. Only flat or hilly races, finishing at high speed and with a relatively high number of contenders (i.e. bunch sprint) have been considered for this study. Furthermore, only events where participants finished within the top 3 positions have been analyzed. As such, a total of nine sprint performances have been analyzed (PRO n: 4, U23 n: 5).

Power output and elevation gain were recorded at 1 Hz using SRM powermeters mounted on the subjects' bikes (PC7, SRM Training System, Jülich, Germany). As suggested by the manufacturer the "automatic zero" setting was turn on the SRM PC7 powermeters. The accuracy and reliability of the SRM powermeters have been previously reported (Abbiss et al. 2009; Gardner et al. 2004). The powermeters' slope was regularly checked during the season with a static calibration, in order to prevent the collection of wrong power data due to a drift in calibration over time. Race files were uploaded online with the web-based service TrainingPeaks, then downloaded and analyzed using the WKO+ 3.0 software (Peaksware LLC, Lafayette, CO, USA).

The peak and average power output, sprint duration and total work were determined for each sprint. Sprint duration was defined as the continuous time elapsed between the start of the sprint (i.e. rapid increase in power) and the end of the sprint (i.e. immediate drop of power), as represented in Fig. 1. Sprint power data were presented as absolute (W), relative to body weight ($W \cdot kg^{-1}$) and relative to projected frontal area ($W \cdot A_p^{-1}$). The power output of the cyclists in the 1, 5 and 10 min prior to each sprint were also determined. In order to describe the external load, power data were presented as absolute (W), relative to body weight ($W \cdot kg^{-1}$), and percentage of the subjects' maximal mean power for 60 minutes ($\%MMP_{60}$) (Quod et al. 2010). Also, total time, average power (W and $W \cdot kg^{-1}$) and total elevation gain of the races were recorded (PC7, SRM Training System, Jülich, Germany).

The projected frontal area (A_p) of the cyclists has been calculated using digital pictures, as previously done in track sprint cycling research (Dorel et al. 2005). A modified version of the method described by Heil (2002) was used. Briefly, frontal photographs of the sprinting cyclists were used to determine the area of the rider and bike and calculated in pixels^2 using a computer based photograph analysis software (Adobe Photoshop 12.0, Adobe System Inc, San Jose, CA, USA). The height of the front wheel was calculated in pixels and used to convert pixels into meters based upon a wheel's height of 0.668m (700c wheel with 23mm tyre). Two pictures for each cyclist were utilized, and the average A_p was used for the analysis (PRO, 0.442 m^2; U23, 0.406 m^2).

Statistical Analysis

Sprint data were compared between PRO and U23 using a one-way analysis of variance (ANOVA) on each dependent variable which met the parametric assumptions. The exercise intensity in the 10 min prior to the sprint was compared using a two-way ANOVA (2 categories x 3 times). When a significant F-value was found, Bonferroni's *post hoc* test was applied.

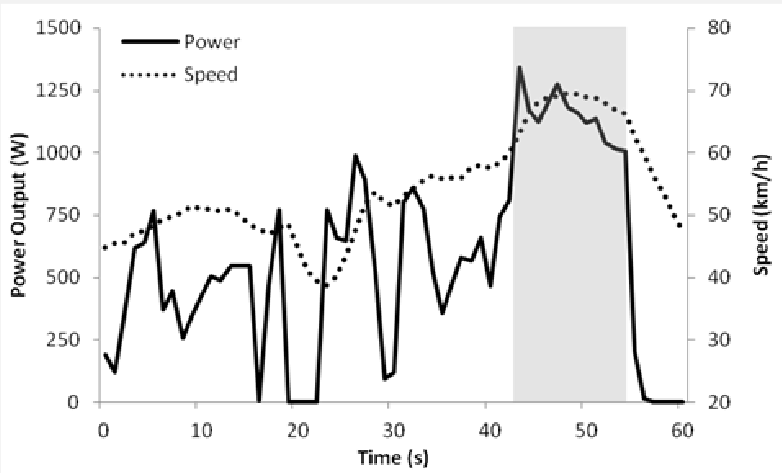

Figure 1. Example of power output and speed recorded at the end of a road race. The final sprint is highlighted in grey.

Critical level of significance was established at $P<0.05$. Results are presented as means ± SD.

Results

Table 1 reports the sprint parameters for PRO and U23. No statistical differences were found in absolute peak and average power, duration and total work. The peak and average power output relative to body weight was higher in the U23 compared to the PRO sprinter. Likewise, average power output relative to projected frontal area was higher in the U23 compared with the PRO.

Table 1. Peak and average sprint power, sprint duration and total work in successful PRO and U23 sprints.

	PRO (n: 4)	U23 (n: 5)	*P*
Peak Power (W)	1370 ± 51	1318 ± 60	0.214
Peak Power ($W \cdot kg^{-1}$) *	19.1 ± 0.7	20.6 ± 1.0	0.034
Peak Power ($W \cdot A_p^{-1}$)	3098 ± 116	3246 ± 148	0.148
Average Power (W)	1120 ± 33	1112 ± 68	0.905
Average Power ($W \cdot kg^{-1}$) *	15.6 ± 0.4	17.4 ± 1.1	0.016
Average Power ($W \cdot A_p^{-1}$) *	2533 ± 76	2740 ± 169	0.016
Sprint Duration (s)	14.5 ± 2.4	12.8 ± 1.1	0.194
Work (J)	16220 ± 2645	14221 ± 1364	0.183

*$P<0.05$

Power outputs in the 10 min prior to the sprint are showed in Table 2. Power output, presented as absolute, relative to body weight and %MMP60, were all significantly higher in PRO than U23. The race intensity prior to the sprint was higher in the final minute compared to the final 5 and 10 min. However, no interactions between categories and time were found.

Total time, average power (W and $W \cdot kg^{-1}$) and total elevation gain of the races were not statistically different between categories: 228±47 min, 213±29 W, 3.0±0.4 $W \cdot kg^{-1}$ and 1295±664 m for the PRO; and 239±11 min, 186±14 W, 2.9±0.2 $W \cdot kg^{-1}$ and 1038±204 m for the U23.

Table 2. Physiological demands of road sprint competitions, before the sprints.

	PRO *			U23		
Time (min)	*1*	*5*	*10*	*1*	*5*	*10*
Power (W) #	450±40	376±28	332±23	385±27	270±26	237±14
Power to weight ($W \cdot kg^{-1}$) #	6.3±0.6	5.2±0.4	4.6±0.3	6.0±0.4	4.2±0.4	3.7±0.2
$\%MMP_{60}$ #	138±13	116±9	102±7	141±10	99±10	87±5

* Significantly different from U23 ($P<0.05$); PRO>U23
# Significantly different between times ($P<0.05$); 1>5>10

Discussion

The purpose of this study was to describe and compare performances in professional and U23 successful male road sprints. The main findings from this study were that: i) the power output (absolute, relative to body weight and relative to frontal area) and total work recorded in successful PRO sprints were similar to successful U23 sprints and, ii) the race intensity (absolute and relative power output) in the 10 min leading into the sprint was higher in PRO compared with U23 races.

Contrary to our hypothesis, the results from the present study indicate that a number of sprint parameters (i.e. scaled to body weight and frontal area) were actually higher in the U23 than in the PRO. Whether this was due to the different body size of the subjects (9 cm and ~9 kg) or to the relatively higher performance level of the U23 sprinter is unclear. However, the aim of the study was to describe the power output necessary to be successful in these categories, as such the data presented here remains relevant in regard to the scope of the study. In particular, the present examination shows that producing a power output > 2500 $W \cdot A_p^{-1}$ (or >15.5 $W \cdot kg^{-1}$) for approximately 14 s, with a peak power output > 3100 $W \cdot A_p^{-1}$ (or >19 $W \cdot kg^{-1}$), can potentially lead to a successful sprint in both the professional and U23 categories. Indeed, previously published data has shown that a professional sprint can be won with an even lower peak (~15.2 $W \cdot kg^{-1}$) and average power output (~12.9 $W \cdot kg^{-1}$) over similar duration (14 s) (Martin et al. 2007). Similarities in power output between the professional and U23 cyclists observed in this study support previous research that has found no difference in 30 s all-out laboratory sprint performance of professional and U23 cyclists (16.0±1.6 and 16.6±1.9 $W \cdot kg^{-1}$, respectively) (Sallet et al. 2006). These laboratory based power outputs are somewhat higher than those observed in this field study and possibly reflect the fact that in road cycling the sprint occurs after hours (>4 h) of riding and following a prolonged period of high intensity cycling as showed in the present study (Table 2).

Interestingly, the relative intensities in the 10 min leading into the finish were higher in the professional races compared with the U23 races. It should be noted that numerous factors may influence a cyclists power output prior to and during a sprint, including physiological characteristics, race dynamics, gradient of the road, wind speed, team support and the ability of the cyclists to position themselves within the bunch appropriately. Indeed, it has recently shown that performances of world class sprint cyclists are related to the team support and the cyclists position within the bunch (Menaspà et al. 2013). As such, it is unclear from the present study if technical and tactical factors influenced the power output, relative intensities and performances of cyclists within this study. Irrespectively, the overall intensity of the events analyzed in this study (3.0±0.4 $W \cdot kg^{-1}$ and 2.9±0.2 $W \cdot kg^{-1}$ for PRO and U23, respectively) were higher than those recorded in professional flat races (2.0±0.4

$W \cdot kg^{-1}$) (Vogt et al. 2007), but similar to the one previously reported in a professional road stage race, with both flat and mountainous stages ($3.1 \pm 0.2\ W \cdot kg^{-1}$) (Vogt et al. 2006).

Calculating sprint power output relative to a cyclist's projected frontal area, as in the present study, is likely to be extremely important to sprint cycling performance. However, it was unfortunately not possible within this study to accurately determine other factors that may influence the calculated sprinters' aerodynamic drag, including air density, wind strength and direction (Martin et al. 2006). Moreover, other variables such as the bike position (standing or seated) and the position in the bunch (front position or drafting) can influence the aerodynamic drag area (Martin et al. 2007). Further research examining the importance and methods of determining road sprint cycling power output relative to projected frontal area and aerodynamic drag area is warranted.

In conclusion, this study highlights the physiological demands of successful road sprints performed by an U23 and a professional cyclist. These data indicate that the physiological demands of male road sprinting were higher in professional races compared to U23 races, in particular the power output in the final part of the race, prior to the sprint. However, a similar sprint power output can theoretically allow a cyclist to win a bunch sprint in either PRO or U23 races.

Limitations of the study

The main limitation of this study is that measures are from two subjects (not really independent measures), at the same time the sample is too small to treat the data as repeated measures. As for all case studies, data collected cannot necessarily be generalized to the general population of road sprinters. Ideally, the study should include more subjects or more measurements. However, it's worth mentioning that there are very few specialist sprinters in the entire peloton with approximately only 1 or 2 per team. Furthermore, the number of races throughout a season whereby these sprinters may be in contention to sprint and ultimately achieve a successful outcome is limited. Considering that all analyzed files were from successful sprint performances, the data presented here are of great value when it comes to describing the physiological demands and characteristics of successful sprints.

Further research examining a greater number of professional and U23 cyclists is needed in order better understand the physical requirements of such sprints.

Practical applications

Describing and understanding the characteristics important to successful road sprinting will assist professionals, coaches, researchers, and athletes in training program development, talent identification and physical load monitoring.

Moreover, matching a rider's characteristics with the demands of competitions can help identifying his strength and weaknesses.

Finally, the awareness that a given rider has the physiological capability to win a road sprint should allow him to focus on other relevant variables, such as technical and tactical aspects, or enhancing the climbing ability to increase chances to be in the first bunch.

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